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'Charleston Scarlet' Sweetpotato

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The sweetpotato [*Ipomoea batatas* (L.) Lam.] cultivar Charleston Scarlet was developed by the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS), Charleston, SC. This cultivar is an orange-fleshed, sweet, fresh-market type with attractive scarlet-colored skin (periderm). Vine growth is vigorous with large cordate leaves that form a dense canopy. 'Charleston Scarlet' is highly resistant to insects and nematodes and moderately resistant to fusarium wilt. Roots store well and have an excellent baking quality with a moist, sweet flesh. Bedded 'Charleston Scarlet' seed-roots produce a large number of uniform sprouts that transplant well. This cultivar flowers and produces seeds profusely and makes an excellent polycross parent for the development of red-skinned, sweet, orange-fleshed cultivars with multiple resistance traits and excellent cooking characteristics. Its high level of insect and nematode resistance may be very beneficial for organic farmers and home gardeners who typically do not use synthetic pesticides.

Origin

'Charleston Scarlet' was developed using a recombinant mass selection breeding technique (Jones et al., 1986). This cultivar originated as a seedling of the maternal parent 'Regal' (Jones et al., 1985) from an open-pollinated polycross breeding block comprised of four randomized replications of 27 parental clones in 1996. Parental clones in the block were selected for high levels of multiple-pest resistance combined with many good horticultural traits. The maternal parent of 'Regal' (W-152) is W-99, whose maternal parent is W-48. Originally, 'Charleston Scarlet' was designated as 97-029 when it was tested as a first-year seedling in 1997 (Jackson et al., 2002a). In 2002, this genotype was redesignated W-375 for further field testing (Jackson and Bohac, 2004; McLaurin, 2003), and in 2006, it was released by the USDA-ARS as 'Charleston Scarlet' (Bohac and Jackson, 2006).

Description

Leaves of 'Charleston Scarlet' are cordate to triangular, shouldered, have small teeth, and are similar in shape to those of 'Beauregard' (Rolston et al., 1987) and 'Ruddy' (Bohac et al., 2002) (Fig. 1). Mature leaves are dark green and similar in color to 'Beauregard' (Table 1). However, the narrow purple border of small and expanding leaves is not as pronounced as in 'Beauregard', and the purple color is not visible on mature leaves. 'Charleston Scarlet' has green-stemmed vines that are long and vigorous, and the canopy develops rapidly and shades the ground more effectively than 'Beauregard'. Sprouting of bedded roots is excellent, and in the 2002 Sweetpotato Collaborator's Trials, plant production of 'Charleston Scarlet' (evaluated as W-375) was comparable or superior to all other regional lines, including 'Beauregard', for the only two locations reporting sprouting data that year (McLaurin, 2003). 'Charleston Scarlet' flowers well without grafting and its high seed production makes it a good parent for a sweetpotato breeding program. The corolla is large and pale lavender with a deep purple throat (Fig. 1). 'Charleston Scarlet' has been included in the main polycross breeding nursery at Charleston since 2000.

In South Carolina, the storage roots of 'Charleston Scarlet' are mostly elliptical and uniformly shaped with a smooth, attractive red skin and medium orange flesh (Fig. 1). The skin of 'Charleston Scarlet' is dark red, and it has a significantly higher a* value (red–green coordinate) and lower hue angle (h*) than other red-skinned cultivars such as 'Regal' (Jones et al., 1985), 'Diane' (Stoddard and LaBonte, 2007), or 'Ruddy' (Bohac et al., 2002) (Table 1). Color saturation chroma (C*) of 'Charleston Scarlet' skin is similar to 'Diane', and lightness (L*) (black–white axis) is similar to 'Regal' (Table 1). The flesh of 'Charleston Scarlet' is an attractive orange color that is similar to the flesh of 'Regal' but is somewhat lighter than the flesh of 'Beauregard', 'Hernandez' (LaBonte et al., 1992), or 'Diane' (Table 1).

'Charleston Scarlet' is a medium-season cultivar (Aguilar and Huamán, 1999), and it is ready to harvest at about the same time as 'Hernandez' (≈120 d after transplanting). In subjective taste panel evaluations, the baked roots of 'Charleston Scarlet' were sweet and moist with excellent color and flavor, comparable to 'Hernandez', but drier and sweeter than 'Beauregard' (Table 2). However, the cooked flesh color is somewhat lighter than 'Hernandez' and 'Diane'. The roots maintain good baking quality and appearance under long-term storage.

Disease Reactions

Resistance of 'Charleston Scarlet' to fusarium wilt [*Fusarium oxysporum* f. sp. *batatas* (Wr.) Snyd. & Hans] was determined by a greenhouse evaluation in 2008. For this test, four replicates of five terminal, field-grown vine cuttings of 'Charleston Scarlet' and four standard sweetpotato cultivars were planted in a randomized complete block design into a steam-sterilized soil bench in a greenhouse. Before planting, each cutting was dipped for 1 min in an aqueous suspension of fusarium wilt adjusted to 1×10^6 propagules/mL. After 17 d, plants were rated on scale of 0 to 5 (0 = no disease to 5 = all plants dead) (Jones et al., 1986).

Resistance of 'Charleston Scarlet' to the southern root-knot nematode [*Meloidogyne incognita* (Kofoid & White) Chitwood] was determined in greenhouse evaluations in 2007 (six replications) and 2008 (four replications). For these tests, five terminal, field-grown vine cuttings of 'Charleston Scarlet' and four standard sweetpotato cultivars were planted in randomized complete block designs into steam-sterilized soil benches in a greenhouse. Each cutting was inoculated with ≈3000 freshly extracted *M. incognita* eggs (race 3) at planting. After 57 d (2007) or 50 d (2008), roots were dug, washed, and evaluated for gall index and egg mass index. For gall index, plants were rated on scale of 1 to 5 (1 = no galling to 5 = greater than 80% of the root system galled). For egg mass index, plants also were rated on scale of 1 to 5 (1 = no egg masses to 5 = greater than 80% of the root system covered with egg masses) (Jones et al., 1986).

From these experiments, it was determined that 'Charleston Scarlet' is moderately resistant to fusarium wilt and highly resistant to the southern root-knot nematode (Table 3) (also see Thies et al., 2008, 2009a, 2009b; Thies and Jackson, 2009a, 2009b). Under field conditions where the susceptible cultivar Porto Rico (Pope and Hoover, 1966) exhibited symptoms of internal cork virus (caused by a strain of the feathery mottle virus), 'Charleston Scarlet' showed no evidence of this disease.

Insect Resistance

Over a 10-year period (1999 to 2008) at the U.S. Vegetable Laboratory, Charleston, SC, 'Charleston Scarlet' was evaluated for resistance to soil insect pests in field evaluations (four replications per year) that included two resistant ('Regal' and 'Ruddy') and two susceptible ('Beauregard' and 'SC1149-19')

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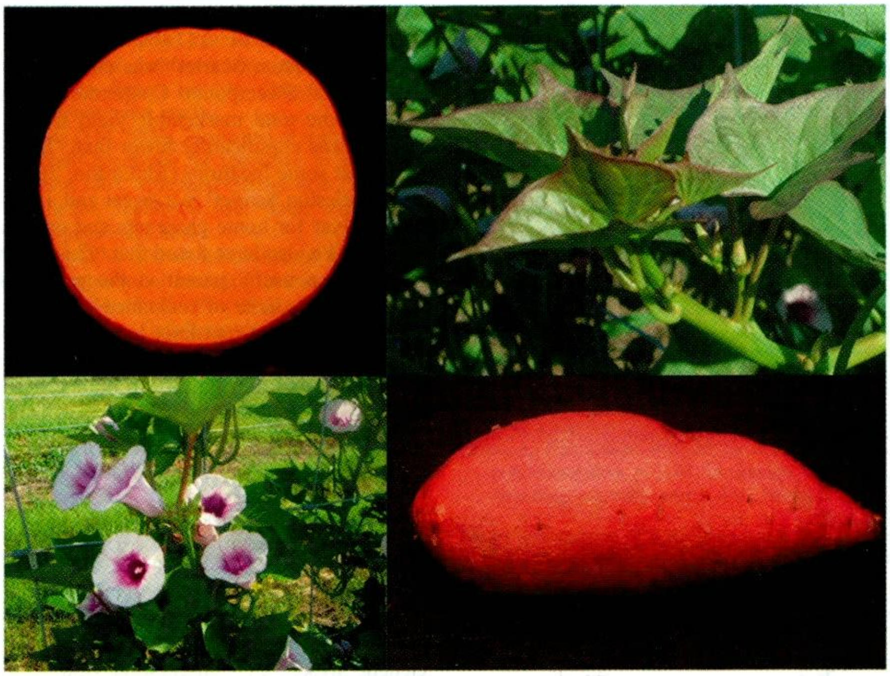

Fig. 1. Root flesh color, leaves, flowers, and a storage root of 'Charleston Scarlet' grown at the U.S. Vegetable Laboratory, Charleston, SC, 2009.

Table 1. Color coordinates of leaves and storage roots of 'Charleston Scarlet' compared with six standard sweetpotato cultivars from field tests at the U.S. Vegetable Laboratory, Charleston, SC, 2007–2009.

Sweetpotato genotype	Color coordinates[z]				
	a*[y]	b*[x]	L*[w]	h*[v]	C*[u]
			Storage root skin color[s]		
Charleston Scarlet	25.4 a[t]	11.9 e	40.5 d	25.1 f	28.2 c
Regal	22.1 b	12.6 e	41.5 d	30.1 e	25.5 d
Diane	21.6 b	18.9 c	47.1 c	41.1 c	28.8 c
Ruddy	19.0 c	14.7 d	45.4 c	38.2 d	24.1 d
Hernandez	18.3 c	29.3 a	54.0 b	58.0 b	34.6 a
Beauregard	16.1 d	24.1 b	55.1 b	56.2 b	29.0 bc
SC1149-19	12.8 e	27.9 a	58.3 a	65.4 a	30.7 b
			Storage root flesh color[s]		
Charleston Scarlet	22.7 c	41.7 d	73.7 ab	61.5 cd	47.5 cd
Regal	22.6 c	44.0 c	72.8 b	63.0 b	49.6 c
Diane	29.2 b	50.0 b	68.2 d	59.7 ef	57.9 b
Ruddy	22.8 c	44.2 c	70.3 c	62.8 bc	49.7 c
Hernandez	32.4 a	52.3 a	66.4 e	58.3 f	61.5 a
Beauregard	28.2 b	50.1 b	68.2 d	60.7 de	57.5 b
SC1149-19	18.8 d	40.8 d	74.3 a	65.7 a	45.0 d
			Leaf color[r]		
Charleston Scarlet	−12.1 a	15.1 b	36.5 NS[g]	128.9 a	19.3 b
Beauregard	−12.8 ab	16.8 ab	35.5	127.7 ab	21.1 ab
Ruddy	−13.3 b	18.4 a	36.8	126.1 b	22.7 a

[z]Measured with a Konica Minolta Chroma Meter (CR-400 with 8-mm aperture and 0° viewing angle) using the CIE 1976 L*a*b* and CIE L*C*h color spaces (HunterLab, 2009a, 2009b; Konica Minolta, 2007a). Data were recorded using Color Data Software CM-S100w SpectraMagic NX™ (Version 1.7) (Konica Minolta, 2007b).

[y]Red–green axis.

[x]Yellow–blue axis.

[w]Lightness (black–white axis).

[v]Hue angle (calculated as $\tan^{-1}$ b*/a*).

[u]Saturation chroma [calculated as square root $(a^{*2} + b^{*2})$].

[t]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Fisher's protected least significant difference) (SAS, 2009); NS = nonsignificant F value in analysis of variance.

[s]For each genotype, three readings were taken from two roots each year (2007 and 2008).

[r]Ten leaves from field plots were measured for each genotype during Sept. 2009.

control sweetpotato cultivars. Individual roots were evaluated for damage from natural infestations of sweetpotato flea beetles (*Chaetocnema confinis* Crotch), white grub larvae (*Phyllophaga* spp. and *Plectris aliena* Chapin), sweetpotato weevils [*Cylas formicarius* (F.)], and the WDS complex (Wireworm, *Diabrotica*, *Systena*). At Charleston, the WDS complex typically includes the southern potato wireworm (*Conoderus falli* Lane), the tobacco wireworm (*Conoderus vespertinus* Fabricius), the banded cucumber beetle (*Diabrotica balteata* Le Conte), the spotted cucumber beetle (*Diabrotica undecimpunctata howardi* Barber), and the elongate flea beetle [*Systena elongata* (F.)] (Cuthbert and Davis, 1971). WDS severity index was calculated by averaging the rating given to each root (1 = one to five holes or scars, 2 = six to 10 holes or scars, 4 = greater than 10 holes or scars). Data for sweetpotato flea beetles, white grubs, and sweetpotato weevils were calculated as the percentages of roots that were damaged by these insects. The percentages of uninjured roots (undamaged by any soil insect pests) also were determined for each entry. Additional details of the methods of testing and evaluation were previously described (Jackson and Bohac, 2006a; Jones et al., 1986). Data were subjected to analysis of variance, and means were separated by Fisher's least significant difference at the 5% probability level (SAS, 2009).

These studies revealed that 'Charleston Scarlet' exhibits a high level of resistance to insect pests. Among the three insect-resistant cultivars ('Charleston Scarlet', 'Ruddy', and 'Regal') in 10 years of field evaluations, there were no significant differences in the percentage roots damaged by sweetpotato flea beetles, white grubs, or sweetpotato weevils (Table 4). However, the WDS severity index for 'Charleston Scarlet' was significantly lower than for 'Regal' but significantly higher than for 'Ruddy' (Table 4). Results of individual years of insect resistance evaluations were reported in Insect Management Tests (Jackson, 2008a, 2009a, 2009b, 2009c; Jackson and Bohac, 2004, 2006c, 2007b; Jackson et al., 2002a, 2002b, 2002c) and The National Sweetpotato Collaborators Group Progress Reports (Jackson, 2008b, 2009d; Jackson and Bohac, 2003).

Jackson and Bohac (2007a) reported that adult *Diabrotica balteata* and *D. undecimpunctata* beetles had significantly shorter longevities when fed exclusively in no-choice experiments on the peel (periderm plus cortex) of 'Charleston Scarlet' (tested as W-375) than they did on the peels of the insect-susceptible cultivars SC1149-19 or Beauregard. In addition, in a separate study, weight gain and survival of *D. balteata* larvae in no-choice bioassays on the peel of 'Charleston Scarlet' were reduced significantly from the susceptible controls (Jackson and Bohac, 2006b). Jackson and Bohac (2006b, 2007a) concluded that both antixenosis (nonpreference) and antibiosis factors contributed to insect resistance in 'Charleston Scarlet'.

Production

When soil moisture is maintained through timely rains or supplemental irrigation, 'Charleston Scarlet' yields well under typical hot and humid summer conditions in South Carolina, where it was similar to 'Regal' and

Table 2. Taste panel evaluations of baked roots of 'Charleston Scarlet' and six standard sweetpotato cultivars at the U.S. Vegetable Laboratory, Charleston, SC, 2006–2008.

Sweetpotato genotype	Flesh[zy] color	Color[x] consistency	Fiber[w]	Flavor[v] (sweetness)	Mouthfeel[u] (dryness)
Charleston Scarlet	3.2 b[t]	3.2 a	2.4 bc	2.5 b	2.5 ab
Hernandez	1.3 d	1.3 b	2.3 bc	2.6 ab	2.3 bc
Diane	1.5 d	1.5 d	2.1 bc	2.9 ab	2.2 bc
Ruddy	2.1 cd	1.9 b	1.6 c	2.8 ab	1.8 c
Beauregard	2.8 bc	1.7 b	1.8 bc	3.5 a	2.0 bc
Regal	2.9 b	3.3 a	3.8 a	2.8 ab	2.6 ab
SC1149-19	4.6 a	3.8 a	2.5 b	2.7 ab	3.0 a

[z]Taste panel consisted of three individuals who tasted two sweetpotatoes each year, 2006–2008.
[y]Subjectively rated 1 (dark orange) to 10 (white).
[x]Subjectively rated 1 (uniform) to 10 (blotchy).
[w]Subjectively rated 1 (smooth) to 10 (stringy).
[v]Subjectively rated 1 (sweet) to 10 (bland).
[u]Subjectively rated 1 (moist) to 10 (dry).
[t]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Fisher's protected least significant difference) (SAS, 2009).

Table 3. Reaction of 'Charleston Scarlet' and five standard sweetpotato cultivars to southern root-knot nematode, *Meloidogyne incognita* race 3, and fusarium wilt in greenhouse evaluations at the U.S. Vegetable Laboratory, 2007–2008.

Sweetpotato genotype	Southern root-knot nematode (race 3): Gall index (1–5)[z]	Egg masses (1–5)[y]	Fusarium wilt index (0–5)[x]
Charleston Scarlet	1.49 c[w]	1.42 c	2.27 bc
Liberty	1.10 d	1.11 d	2.93 b
Ruddy	1.09 d	1.07 d	1.43 cd
Sulfur	4.45 b	4.28 b	4.70 a
Beauregard	4.79 a	4.69 a	0.55 d

[z]Gall index. Plants rated on scale of 1 to 5; 1 = no galling to 5 = greater than 80% of the root system galled.
[y]Egg mass index. Plants rated on scale of 1 to 5; 1 = no egg masses to 5 = greater than 80% of the root system covered with egg masses.
[x]Disease index. Plants rated on scale of 0 to 5; 0 = no disease to 5 = all plants dead.
[w]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Fisher's protected least significant difference) (SAS, 2009).

Table 4. Injury by soil insect pests on roots of 'Charleston Scarlet' compared with two resistant ('Regal' and 'Ruddy') and two susceptible ('Beauregard' and 'SC1149-19') control sweetpotato cultivars from 12 field tests at the U.S. Vegetable Laboratory, Charleston, SC, 1999–2008.

Sweetpotato genotype	Percent uninjured roots	WDS[z] severity index	Percent SPFB[y]-injured roots	Percent Grub[x]-injured roots	Percent SPW[w]-injured roots
Ruddy	77.3 a[v]	0.13 a	2.5 a	8.5 a	1.8 a
Charleston Scarlet	69.1 b	0.26 b	3.6 a	6.7 a	2.9 a
Regal	60.9 c	0.37 c	1.6 a	4.5 a	3.0 a
Beauregard	26.4 d	0.81 d	15.6 b	21.5 b	19.3 b
SC1149-19	11.0 e	1.01 e	35.8 c	27.7 c	35.5 c

[z]WDS = Wireworm, *Diabrotica*, *Systena* complex. Severity index: 1 = 1–5 scars, 2 = 6–10 scars, 4 = more than 10 scars, averaged over total number of harvested roots.
[y]SPFB = Sweetpotato flea beetle, *Chaetocenema confinis* Crotch.
[x]Primarily *Plectris aliena* Chapin.
[w]SPW = Sweetpotato weevil, *Cylas formicarius* (F.).
[v]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Fisher's protected least significant difference) (SAS, 2009).

Table 5. Average yields of 'Charleston Scarlet' compared with four standard sweetpotato cultivars over eight field tests in Bamberg and Barnwell Counties, SC, 1999–2003.

Sweetpotato genotype	Avg yield[z]: U.S. #1[y]	Canners[x]	Jumbos[w]	Culls	Total[v] yield	Percent U.S. #1	Percent dry wt
Beauregard	32.2 a[u]	19.1 bc	5.4 a	3.3 bc	57.6 a	57.3 a	19.6 b
Charleston Scarlet	28.5 ab	22.1 ab	2.7 bc	2.5 c	53.3 ab	45.8 b	27.9 a
Regal	21.8 bc	26.2 a	1.1 bc	8.0 a	49.1 ab	42.2 b	22.2 b
SC1149-19	22.9 b	21.5 ab	0.3 c	2.8 bc	44.6 b	46.5 b	26.7 a
Jewel	15.9 c	15.1 c	3.0 ab	5.5 ab	34.1 c	45.0 b	25.9 a

[z]Yield in metric tons per hectare.
[y]U.S. #1 = Roots 5.1 to 7.6 cm in diameter, length of 7.6 to 22.9 cm, well-shaped and free of defects.
[x]Canner = Roots 2.5 to 5.0 cm in diameter, 5.1 to 17.8 cm in length.
[w]Jumbo or oversize = roots that exceed the diameter, length, and weight requirements of the above two grades, but are of marketable quality.
[v]Total marketable yield = sum total weight of roots classified as U.S. #1s, Canners, and Jumbos.
[u]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Fisher's protected least significant difference) (SAS, 2009).

'Beauregard' in the production of well-shaped roots (US #1's) (Table 5). However, when 'Charleston Scarlet' was entered into the National Sweetpotato Cooperator Trials in 2002, the total marketable yield for this cultivar was significantly lower than 'Beauregard' at some locations (McLaurin, 2003).

'Charleston Scarlet' is a sweet and attractive cultivar for home gardeners and organic farmers. We also have found that 'Charleston Scarlet' is a useful parent in the polycross nursery as a source of resistance to insects, fusarium wilt, and root-knot nematodes. Because 'Charleston Scarlet' has multiple pest resistances, dark red skin, deep orange flesh, attractive shape, and good flavor, it is valuable to sweetpotato breeders for use as a parental line to develop resistant commercial orange-fleshed cultivars.

Availability

'Charleston Scarlet' (accession number PI 653843) is available as tissue-cultured plantlets from the Sweetpotato Clonal Repository, Plant Genetic Resources Conservation Unit, 1109 Experiment Street, Griffin, GA 3223-1797 (http://www.ars-grin.gov/cgi-bin/npgs/html/site.pl?S9), where it is available for research purposes, including development and commercialization of new cultivars. It is requested that appropriate recognition to USDA-ARS be made if this germplasm is used in catalog descriptions or contributes to the development of a new breeding line or cultivar.

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